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Energy certification of existing office buildings: Analysis of two case studies and qualitative reflection

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ABSTRACT

Energy efficiency in buildings is of particular importance in the pursuit of international objectives in the area of climate and energy, as it is a sector that represents approximately 40% of the total primary energy demand in the world, with expected strong growth. In Portugal, the current Building Energy Certification and Indoor Air Quality System (known as SCE) is intended to be an important step in the promotion of energy efficiency and reduction of greenhouse gas emissions. This work presents the application of the SCE system to two large office buildings in the Lisbon area: an historical building (the Lisbon City Hall, built in the late XIX century) and a contemporary office building. In the context of the SCE energy audits to these two buildings, a cost–benefit analysis of different energy optimization scenarios was performed based on calibrated building thermal simulation models. The two case studies, being very different between themselves, represent opposite contexts in which the SCE can be applied to existing buildings and thus the results constitute a suitable basis to examine the principles and energy indicators used in this and other certification schemes, resulting in a qualitative reflection on the limitations of the SCE and opportunities for its improvement.

1. Introduction

In the European Union (EU), increased building energy performance is a central tool to reduce energy dependency, having the imports in 2010 represented about 54% of the total internal consumption (European Commission, 2012a), and comply with existing carbon dioxide emission targets (European Commission, 2011a, 2011b). The building sector represents approximately 40% of the total final energy demand, with strong growth prospects in a business as usual scenario (Buildings Performance Institute Europe, 2011). Buildings typically have a lifespan of several decades and therefore refurbishment of existing buildings is an important element of the EU energy and climate strategy. In Europe, in each year about 1.2% of the building stock is renovated and 0.1% is demolished (EuroACE, 2011). In this context, building energy certification and labeling is a key policy instrument that provides decision makers in the building construction and refurbishment industry with objective information on a given building, either in relation to achieving a specified level of energy performance or in comparison to other similar buildings (International Energy Agency, 2010). EU has currently an ambitious strategy for deep renovations supported by the 2012/27 Energy Efficiency Directive (European Commission, 2012b). Theoretical framework and a practical tool for its implementation is provided in (BPIE, 2013).

Energy certification schemes can be applied to both new and existing service and residential buildings. These schemes are a subset of whole building environmental assessment schemes. The most well-known whole building qualitative assessment voluntary schemes are the Building Research Establishment Environmental Assessment Method in the UK (BREEAM, Environmental Assessment Method, 2012) and Leadership in Energy and Environmental Design (LEED) in the United States (USGBC, 2013). Both these voluntary schemes are increasingly being used internationally, e.g. by government agencies, as a basis for specifying minimum building environmental performance. Compared to mandatory schemes, voluntary schemes tend to be easier to implement because they are typically introduced in developed markets and are based in well-established quality assurance methods (Mlecnik, Visscher, & Van Hal, 2010). To date, most countries have chosen to adopt voluntary rather than mandatory whole building certification schemes. Mandatory schemes can be implemented in order to include all buildings, while voluntary certification schemes tend to include only buildings that have high energy performance ratings (International Energy Agency, 2010) that then tend to act as a benchmark for those markets.

In the EU, whole building environmental assessment is voluntary but energy certification is mandatory. It is the result of the transposition into national law of the EU Energy Performance

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of Buildings Directive (EPBD) (European Commission, 2002). This directive promotes the adoption of measures that maintain or raise indoor comfort levels while reducing building energy consumption. The guidelines for achieving these improvements are based on (1) adopting a common methodology to verify the energy performance of buildings, (2) defining minimum levels of energy efficiency applied to new and existing buildings that are submitted to large retrofitting, (3) creating energy certification schemes and (4) implementing mandatory periodical inspections for boilers and HVAC systems. More recently the European Commission considered the EPBD requirements should be extended through a recast (European Commission, 2010). This recast extends the existing directive by promoting the construction of nearly zero-energy buildings (nZEB) with a high incorporation of renewable energy. The nZEB definition adopted is vague, having the term "nearly" the possibility to be interpreted in several ways. This lack of definition is a direct result of the fact that the nZEB concept still requires a clear single definition and a commonly agreed energy calculation procedure (Marszal et al., 2011). Within the EU, the Comission is meanwhile promoting the reaching of a common nZEB understanding (BPIE, 2011). The work presented in this paper was developed within the framework of the 2002 EPBD and is unaffected by the guidelines introduced in 2010.

The introduction of the SCE energy certification scheme in Portugal (Ministério da Economia e da Inovação, 2006a) is the result of the transposition into Portuguese law of the 2002 EPBD. There are two main decrees that support the application of this system: RCCTE (Ministério da Economia e da Inovação, 2006b) and RSECE (Ministério da Economia e da Inovação, 2006c). RCCTE is applicable to residential and small service buildings (<1000 m^2 of net floor area) equipped with heating, ventilation and air conditioning (HVAC) systems of up to 25 kW (thermal power). RSECE is applicable to large services buildings (>1000 m^2) and small buildings equipped with HVAC systems with more than 25 kW of thermal power. Both regulations have certain limitations that should be addressed. (Ferreira & Pinheiro, 2011) analysed the flaws of the current version of RCCTE using a case study. In the present study we will focus on RSECE faults.

The aim of this paper is to analyze the application of the Portuguese energy certification system and regulation to the existing tertiary sector through the examination of two case types. This paper presents comprehensively the methodology and, after, the results of the application of the SCE energy certification scheme to two large existing buildings, the Lisbon City Hall (5400 m^2), a historical building, and tower five of the Arquiparque complex (6548 m^2), a contemporary building, both under RSECE. Surveys were conducted and documentation consulted in order to characterize all relevant aspects of the energy demand of these buildings (construction and geometry, HVAC, lighting, electrical appliances, occupancy and habits of use). Different optimization energy scenarios were tested.

The buildings are chronologically apart about 130 years from each other, thus are very different in constructive solutions, space use, etc. (see Section 3), representing each one the archetype of a service building from its own time. These particular buildings were chosen because they represent opposite contexts in which the SCE can be applied; for this reason, they constitute a fruitful basis to examine the principles and energy indicators used in this and other alike certification schemes. Their similarities and differences are exploited, resulting in a qualitative reflection on the limitations of the SCE and opportunities for its improvement. Findings and lessons learned are discussed within sections.

1.1. Structure

Since RSECE is the legislation that it is in the basis of the present work, in Section 2 it is presented a brief overview of the method of application of RSECE to existing buildings, including the definition of its main parameters. The methodology followed in this study is presented here. Section 3 begins with a description of the most relevant characteristics of the two case studies (Sections 3.1 and 3.2). It continues with a description of the simulation models, including its main inputs and calibration process (Sections 3.3 and 3.4). Results obtained in the different sets of simulations, with discussion, are presented in Sections 3.5–3.7. In Section 4 are presented the energy saving measures proposed and its impacts in different scenarios. After these sections, when the reader it is already in known of the particularities of RSECE, it is opportun to present in Section 5 a qualitative approach to the limitations found in the SCE system. Some of the improvements discussed are sustained with the use of the results from earlier sections. In Section 6 conclusions of the work are presented as well as concrete perspectives for further development of the concepts proposed.

2. Adapted approach

The methodology followed in this study and calculation of parameters has as basis the SCE framework. Under RSECE, the overall energy performance of a building is summarized by an index of primary energy consumption, the Energy Efficiency Index (EEI), in kgoe/m^2.year (where *oe* stands for oil equivalent). The index is obtained using detailed thermal simulation. There are four types of EEIs, as seen on Table 1.

Depending on the value of these indexes, existing buildings may have to undergo an energy rationalization plan (ERP), as shown in Fig. 1. The $EEI_{STANDARD}$ index is used in the end of the certification process to define the building energy certification rating (see Section 3.7).

In addition to the energy component, SCE has an indoor air quality component that is meant to ensure minimum air change rates and compliance with the maximum concentrations of a set of pollutants, microorganisms and radon. The indoor air quality (IAQ) component of the certification process was not performed in the present study. An interesting example of the application of this component of the method is presented by (Asadi, Costa, & Gameiro da Silva, 2011).

The approach method we took can be schematized as Fig. 2 illustrates. In this figure ARC stands for Annual Registered Consumption; ASC for Annual Simulated Consumption; M_iRC for Monthly *i* Registered Consumption and M_iSC for Monthly *i* Simulated Consumption, being *i* the months from January till December.

3. Case studies

To present the applicability of the SCE to existing buildings and, from there, critically appreciate the system we have chosen two buildings that symbolize opposite contexts in which the SCE can be applied. As previously introduced, the two buildings that constitute the case studies on focus are chronologically apart about 130 years from each other (one from mid XIX century and another one from late XX century), thus are very different in constructive solutions, space use, etc. (details are provided in the next subsections), representing each one the archetype of a service building from its own time. Table 2 presents an overview of the features of the two buildings analyzed. One can see that the useful areas of the buildings are not very different (contemporary building net floor area is about 20% higher than the historical), but the same does not happen with occupation density: contemporary building